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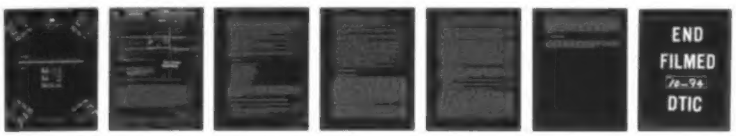

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13. ABSTRACT *(Maximum 200 words)*

We are developing physiological indices of mental workload that could be used in operational environments, including high performance aircraft. Our efforts during the current report period focused on obtaining and analyzing a set of experimental data designed to systematically vary mental workload while holding stimulus- and response-related factors constant. Data were collected from eight subjects in an experiment that taxed spatial and verbal working memory functions whichare critical for performance of most complex tasks. We analyzed the performance data from all subjects, and performed the exploratory electrophysiological signal processing on several subjects. Results so far suggest that there is sufficient level of workload-related signal to perform single trial pattern recognition analyses on these data. We have also designed and implemented a second experiment which will stress subjects' attentional multiplexing capabilities, ie. their ability to do several tasks concurrently. This experiment more closely resembles the tasks pilots are faced with in the cockpit, and will provide an important test of the ability to classify workload levels regardless of the specific type of mental effort or behavior involved.

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I. BACKGROUND

We proposed to build a data collection and software workbench, called the Workload Assessment Research workstation (WAR Station), to facilitate research on mental workload. The WAR Station is to include hardware and software for collecting electrophysiological and behavioral data associated with tasks used in mental workload research and a collection of software tools for analyzing these data with the goal of building and testing practical mental workload indices. The indices would be based on a neural-network analytic paradigm used in our prior research (Gevins, 1980; Gevins and Morgan, 1986, 1988).

Much of this system builds on hardware and software under development in other projects at SAM Technology. The major work required of this project includes

1) designing, implementing, and testing an improved neural network algorithm;

2) performing experiments to provide an initial test of the utility of our analytic approach for building practical indices of mental workload;

3) building the WAR Station by integrating workload-specific software with software and hardware components developed under other projects at SAM Technology; and

4) surveying Air Force researchers to determine desirable system features and work out what data import capabilities will be needed.

These four items reflect an approved revision of our Statement of Work which consisted of appending the second item to our work plan and postponing integration of our system with commercial moving-base flight simulators until Phase III.

II. SUMMARY

Report Period, 16 DEC 92 to 31 AUG 94

Alan Gevins, Principal Investigator

Harrison Leong, Chief of Engineering

Michael Smith, Principal Neuroscientist

Linda McEvoy, Psychophysiologist

Sue Whitfield, Research Associate

Georgia Rush, Research Associate

Paulo Raffaelli, Programmer

Behram daCosta, Programmer

During this period we collected a large amount of data in a working memory paradigm and have performed much of the initial data preprocessing that is prerequisite to neural network pattern recognition analyses. We have also designed a second experiment which will allow us to determine whether workload-related EEG features can be extracted from a more demanding experiment, one which more closely resembles the tasks pilots are required to perform. Finally, several manuscripts were prepared and submitted for publication.

III. PAPERS PUBLISHED AND/OR SUBMITTED DURING THIS PERIOD

Gevins, A.S., et al. (In Press, 1994) Towards measurement of brain function in operational environments. *Biol. Psychol.*

Gevins, A.S., Cutillo, B.A., and Smith, M.E. (Submitted) Regional modulation of high resolution evoked potentials during verbal and nonverbal matching tasks. *Electroenceph. Clin. Neurophysiol.*

Leong, H. & Gevins, A. (Submitted) Unobtrusive assessment of mental workload with neural network classification of physiological signals. *Human Factors*

Le, J., Menon, V. and Gevins, A.S. (In Press, 1994) Local Estimate of Surface Laplacian Derivation on a Realistically Shaped Scalp Surface. *Electroenceph. Clin. Neurophysiol.*

Gevins, A.S. (In, Press, 1994) Imaging the neurocognitive networks of the human brain. In: Erin Bigler (Ed.), *Handbook of Human Brain Function: Neuroimaging,* Plenum Press.

Gevins, A.S. (In, Press, 1994) High Resolution EEG Studies of Cognition. *Epilepsy and Funtional Anatomy of the Frontal Lobe,* Raven Press.

Gevins, A.S., et al. (1994) Subdural grid recordings of distributed neocortical networks involved with somatosensory discrimination. *Electroenceph. Clin. Neurophysiol., Vol. 92 (4),* Elsevier: Amsterdam, pp. 282-290.

Gevins, A.S., et al. (1994) High resolution evoked potential technology for imaging neural networks of cognition. In: Thatcher, R.W., et al. (Eds.), *Functional Neuroimaging: Technical Foundations.* Academic Press, Inc. : Orlando, pp. 223-231.

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Wikswo J.P., Gevins, A.S., Williamson S. J. (1993) The future of the EEG and MEG. *Electroenceph Clin. Neurophysiol., Vol. 1,* Elsevier: Amsterdam, pp. 1-9.

Gevins, A.S. (1993) High-resolution EEG enters imaging arena. *Diagnostic Imaging,* pp. 77-84.

IV. PROGRESS REPORT

Working Memory Data Base

Working memory, that is, the process of maintaining information for several seconds while it is being utilized in focused thought, is critical to performance in complex task environments. We designed an experiment to determine whether neural network based pattern recognition could use physiological features to distinguish between 3 levels of difficulty on a working memory task, whether these features would generalize across task versions that were matched on stimulus, response, and difficulty parameters, but that differed in the type of cognitive processing required (spatial versus verbal working memory), and whether these features were reliable enough to generalize across testing sessions. In the test we implemented, stimuli were presented in a continuous sequence and the subject was required to compare the current stimulus with those earlier in the sequence. Each stimulus was selected from a set of twelve capital letters, and displayed in one of twelve screen positions. Subjects were required to compare the current stimulus to the immediately preceding stimulus (low workload level) or the the stimulus that occurred two trials ago (intermediate workload level) or the stimulus that occurred three trials ago (high workload level). In the verbal processing task version, the subject was required to determine whether the current stimulus letter matched the previous letter. In the spatial processing version, the task was to determine whether or not stimuli appeared in the same spatial location.

Eight subjects participated in three days of testing. The 6 tasks (three levels each of the verbal and spatial versions) were presented in blocks of 20 trials. Each subject performed 8 repetitions of each block per day. The blocks were presented in random order. Subjects made a button press response with the right finger if the current stimulus matched the target stimulus (that presented one, two or three trials ago), or with the left finger if the current stimulus did not match the target. After each block, subjects reported their subjective impression of the task by performing the Subjective Workload Assessment Test (SWAT). The EEG was recorded continuously from 27 scalp electrodes referenced to digitally-linked mastoids, and

the EOG was recorded from four eye electrodes. The passband was 0.05 to 100 Hz, and data were sampled at 256 Hz. Four subjects participated in a call-back session approximately one month after the initial experiment. Of these four subjects, three came for a second call-back session one month thereafter. Each of these call-back sessions comprised one day of recordings in which subjects performed nine repetitions of each block. This call-back data will be used to determine the reliability of the algorithm to classify data over time.

Analysis of the behavioral and subjective data indicate that the experimentally-defined workload levels did indeed differ in difficulty. Both reaction time and accuracy showed significant effects of workload level with subjects showing a monotonic increase in reaction time and decrease in accuracy from the lowest to the highest workload level. The SWAT measures indicated that subjects found the three levels to significantly differ in difficulty, with the lowest level being the easiest and the highest level the hardest. No significant differences were observed between the verbal and spatial versions of the tasks.

The physiological data have been manually reviewed for artifacts. Eye blinks and eye movement artifacts have been filtered out of the EEG data, and trials containing other types of artifact have been excluded from further analysis. Initial exploratory frequency domain analyses have also been performed for several of these subjects to determine whether reliable spatiotemporal features existed in their EEG that discriminated workload levels. Results to date indicate that there is sufficient workload-related signal to justify performing single trial pattern recognition analyses on these data. Thus we will first examine whether such an approach will be successful in discriminating the three workload levels. If this is successful we will then examine the reliability of this index by testing whether networks trained on the data collected from two days will be able to correctly classify the data collected on the other day. Third, we will examine the generality of our workload index by examining whether a network trained on data from the verbal condition can accurately classify workload levels in the spatial condition. Lastly, we will examine the possibility that information content of a task influences spatiotemporal features of the EEG by attempting to explicitly train a network to discriminate between spatial and verbal task performance.

Divided Attention Data Base

Divided attention, the ability to simultaneously allocate attention to multiple tasks, is of fundamental importance in piloting an aircraft. We have designed an experiment to assess subjects' ability to perform several tasks at once, each of which emphasize a different collection of mental resources, and have begun to collect pilot data. EEG, eye movement and blink potentials, and EKG will be recorded while subjects perform three different neurocognitive tasks simultaneously. The subcomponents of this task exercise different mental resources; they include:

Working Memory--maintaining information for several seconds while it is being utilized in the context of a mental task;

Dynamic Visuospatial Reasoning--rapidly coordinating behavior with information about the location and speed of moving objects; and,

Arithmetic Reasoning--mentally solving simple mathmetical equations.

The working memory, dynamic visuospatial reasoning, and arithmetic tasks are concurrently presented on different regions of a computer screen. Each task requires a speeded finger-press response. To make a response to a specific task, the subject must press the left or right button of the left-handed mouse to move the cursor to the desired task. The subject then responds to the task with a left or right mouse button press of the right-handed mouse. In the working memory task, stimuli are presented continuously, and the subject must compare the current stimulus with the immediately preceding stimulus, and make a "match" or "mismatch" button press response. In the dynamic visuospatial reasoning task the subject must make a button press response at the appropriate time so that a "missile" fired from a stationary letter intercepts a target letter travelling vertically across the screen. In the arithmetic reasoning task, the subject must mentally solve a simple mathematical equation and indicate with the appropriate button press, whether the outcome is greater or less than 5. Each task has a limited time for response, so subjects must move quickly among the tasks to perform well in the experiment. Each task has a control level: in the visuospatial task, any button press during the task will successfully intercept the target; in the arithmetic and working memory tasks, the words "left" and "right" will appear, requiring a left or right button press response. The control tasks thus have similar visual and motor requirements as the active tasks, but

do not require the subjects to solve the tasks. Control and active tasks will be presented in different combinations, ranging from all three control tasks at once, to all three active tasks at once. Intermediate levels will have one or two control tasks with two or one active tasks, respectively. Performance data and SWAT data will be collected and analyzed. The physiolgical data will be analyzed in the same way as the working memory data. The ongoing EEG data will be divided into short segments, and the the frequency spectra will be calculated. Spectral features most likely to distinguish between difficulty levels will be subjected to neural network pattern recognition analysis to determine whether we can distinguish the EEG patterns associated with the more demanding conditions from those associated with the easier conditions.

V. CONCLUSIONS

These experiments will provide the necessary database to determine whether our neural network approach can be used to reliably classify different levels of mental workload. We will begin the neural network analysis on the existing, working memory data set immediately. We will also proceed with the piloting and actual data collection for the divided attention experiment.

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